Section of Odontology

President—B. Maxwell Stephens, L.D.S.E.

[*March* 22, 1943]

The Dental Epithelium and its Significance in Tooth Development

By W. Warwick James, O.B.E., F.R.C.S. and A. W. Wellings, D.Sc., M.D.S.

In the present circumstances it is only possible to publish a summary of the paper read before the Section in March with a limited number of illustrations. It is hoped a fuller publication may be possible later.

The Dental Epithelium we have defined as "The Special Epithelium concerned with the development, eruption and fixation of teeth".

It has two chief functions, one the formation of the teeth and the other, the determination and maintenance of their position. It is the latter with which we are concerned in this paper. The former has previously received nearly all the attention of investigators.

The following functions can be attributed to the dental epithelium: (*a*) The production, directly and indirectly, of the dental tissues. (*b*) The determination of the shape of the tooth. (*c*) Fixation of the exact position in which a tooth will develop and the point at which it will erupt. (*d*) The formation of an almost complete epithelial envelope as a capsule enclosing the germ or tooth during the whole process of development, including complete eruption. (*e*) Maintaining connexion between the epithelial envelope and the surface epithelium by means of the connecting dental epithelium.

A factor of much importance when considering the changes occurring in the dental epithelium is the rapidity and extent of its growth.

We found it necessary to extend our investigation to all vertebrates with teeth, for it seemed reasonable to suppose that the process of tooth production is essentially the same throughout. It is only possible to make generalizations which apply to this very wide field.

Source of Material: Stock-animals have been obtained from the laboratories in which we work: The Bland-Sutton Institute of the Middlesex Hospital and the Dental Research Laboratory of Birmingham University, where most of the work has been done during the war. A large number of rare and other specimens has been obtained from the London Zoological Society for more than ten years, and it is upon much of this material that our paper depends. Many friends have procured specimens and serial sections were lent by Dr. Fish (pike) and Mr. Manley (conger eel). Laboratory animals such as frog, kitten and rat were used for precise intervals of age, and for comparison with those less easily procured. It was found necessary to employ the celloidin paraffin method for nearly all specimens. Many sections have been cut which are not good enough for detail, although the dental epithelium is sufficiently well shown to give some indication of its importance. Failure to obtain really good fixation was a frequent difficulty. In the case of the rare animals specimens were often procured only after they had been dead for many hours. Such material is valuable although imperfect. This also applies to our native animals many of which had not been fixed for some hours after death. Fixation by spirit has been most unsatisfactory although material so preserved has been cut when none other has been available. It is obvious that examination of all animals is an impossibility, but selected types at varying ages have been studied, and in each case serial sections were prepared and different staining methods employed (Wellings, 1938).

There appear to be four sites of origin of dental germs from the dental epithelium:

(1) From the surface epithelium. (2) From the sheath epithelium. (3) From a persistent dental lamina. (4) From a non-persistent dental lamina.

(1) Origin from the surface epithelium occurs in some of the superficial teeth of teleostei, e.g. pike (fig. 1). It is described by Harrison (1901) in sphenodon, by Bolk (1912) and Woerdeman (1919) in *Crocodilus porosus.* They are akin to dermal denticles. The initial tooth of a dental unit may be of this nature in some animals, e.g. frog. Röse (1891) described it in Triton.

(2) Origin from the sheath epithelium of a preceding tooth. It occurs in the teleostei, e.g. the garpike, the eel, catfish, pike and mackerel, &c. (figs. 1, 2, 3). It is a method of replacement by successional teeth.

(3) Origin from a persistent dental lamina occurs in the selachii, amphibia and most reptiles. The successional germ arises near the terminal margin (figs. 4, 5, 9).

(4) Origin from a non-persistent dental lamina occurs in marsupials and mammals (fig. 6). It proliferates to produce the connecting dental epithelium, its continuity as

a lamina being lost at an early stage. This is well shown in figs. 8 and 9 of the paper by Röse (1891) in which his reconstruction models are described.

Once initiated the dental epithelium can be readily placed under headings which define areas with special morphological and functional attributes.

(1) The Epithelial Framework and the Dental Zone. (2) The Dental Unit. (3) The Epithelial Envelope: (*a*) coronal part; (*b*) sheath epithelium or subcoronal part. (4) The Dental Lamina and the Connecting Dental Epithelium. (5) The Surface Dental Epithelium.

(1) The Dental Epithelial Framework and Dental Zone

Following initial proliferation from the surface epithelium an extensive production of dental epithelium occurs throughout the tooth-bearing area, with the formation of an epithelial framework composed of surface epithelium connecting a series of units made up of teeth and successional germs. The total area for purposes of description can be called a "Dental Zone". A sufficiently sharp distinction exists between teeth and dermal denticles to define the limit of a zone; in higher types it is easily recognized. Sections through the dental zone show dental epithelium which can be connected together only by examining serial sections, to give a complete picture, as in dog-fish, pike, eel, lizard, snake and man, &c. (figs. 1, 4, 7, 8 show one plane). The connexions seen in one section may be in part continuous or scattered. In the lower forms continuity is readily established in a few sections but in higher forms many of a series may need to be examined (James, 1909).

The dental zone is composed of the surface epithelium connecting a series of units, which correspond in number with each erupted tooth and its successors. Each of these individual groups we have named a dental unit.

The recognition of an epithelial framework indicates a continuity which is maintained between all the dental elements, whatever changes of proliferation, maturity or degeneration the dental epithelium undergoes.

Although the initial changes are seen in the dental epithelium, they are soon followed by the induction of important differential changes in the mesoderm. The resulting mesodermal structures, not only those forming the teeth, must be regarded as belonging to the dental zone.

(2) The Dental Unit

This is an entity in the epithelial framework of the dental zone consisting of an erupted tooth and its successor or successors connected by dental epithelium. In polyphyodont animals the individual tooth and its successors are always connected by dental epithelium forming a chain consisting of a formed tooth, a developing tooth, and one or more following dental germs. A similar arrangement holds in diphyodonts.

No lateral communication occurs between dental units except at the surface (figs. 1 and 7). Where the germs are attached to a persistent dental lamina, this also provides further lateral communication (figs. 5 and 9).

Whether there is a stage of discontinuity in any animal with later reunion of the dental epithelium is extremely doubtful.

The condition in crocodilia is unusual where the replacing tooth germ soon passes into the pulp chamber of the functional tooth in which position its development is completed. In due course as the old tooth becomes cast off, surface continuity of the new tooth is established by the junction of its epithelial envelope with the surface epithelium (fig. 10).

Within the unit continuity is maintained by means of the epithelial envelope, the connecting dental epithelium and the surface dental epithelium.

Successional teeth and germs are grouped by Bolk as "families".

(3) The Epithelial Envelope

An envelope of dental epithelium which encapsules the forming tooth throughout development including attainment of final position, is formed by the outer layer of cells of the enamel organ and is complete, except where the mesodermal tissues of the tooth are being produced at its base. When fully developed it consists of two parts (*a*) a coronal, and (*b*) an extension over the subcoronal part of the tooth. Externally it is in contact with the surrounding mesoderm except where it has attachment to the connecting dental epithelium. It is readily recognized in all animals (figs. 8, 10, 11, 12, 13, 20, 21).

As the developing tooth increases in all dimensions so the envelope grows by proliferation of its cells. Provision for increase in depth is made by proliferation of the cells at the base of the enamel organ. This extension of the envelope over the subcoronal part of the tooth constitutes the "sheath epithelium". It is important to realize that the two parts are continuous.

We are of the opinion that the coronal part of the envelope, the connecting dental epithelium and the surface dental epithelium, are chiefly responsible for the positioning of the tooth, and are aided by the sheath epithelium as the formation of the subcoronal part of the tooth progresses.

(*a*) *The coronal part of the epithelial envelope:* The outline of the epithelial envelope varies at its successive stages and with different types of animals. In the lower forms it roughly corresponds with the shape of the tooth. In the higher forms, where the germs are more deeply situated and a stellate reticulum is often present in the earlier stages, it has a more or less globular outline rendered superficially irregular by proliferating buds and processes on its coronal part (figs. 16, 17, 18).

Deeply situated germs in the lower forms present some of these characteristics. In the wrasse, cichlid (figs. 8 and 11) and others there is marked proliferation of the coronal epithelium, producing the gland-like appearance described by Mummery in *Sargus ovis* to which he ascribed a secretory function.

In polyphyodont animals with a persistent dental lamina (selachii, amphibia and some reptilia) the epithelial envelope is attached to the lamina along which, as the tooth grows, it appears to move until it joins the surface epithelium to form the attachment (fig. 5).

In diphyodont animals in the early stages where the dental lamina is non-persistent, as proliferation progresses the epithelial envelope is connected to the lamina in a manner which varies in complexity, with different teeth and at different stages. Thus the envelope may be attached to the lamina directly, or by a strand of cells at one stage, while at another the two-strand phase described by Bolk (1921) may be seen, and at other stages the connexions may be still more complex as a network (figs. 14, 15, 16, 17 and 18). The detailed arrangement needs further study. It is sufficient at present to direct attention to the fact that the epithelial envelope and the lamina forming the connecting dental epithelium, are not in a static condition.

In crocodilia the enamel organ is of particular interest on account of the importance attached to it by Bolk (1921). In a specimen from a spectacled caiman (*Caiman crocodilus*) (fig. 19) the envelope dips in at its summit to form a depression, similar to an "enamel navel", from which a condensation of cells, an "enamel septum", divides the stellate reticulum in a manner described by him as occurring only in mammals. It would thus seem that the part of his dimeric theory which is based upon the occurrence of these phenomena only in the mammalian enamel organ, is unsound.

Throughout development epithelial projections into the mesoderm are constant and have a definite distribution over the summit of the envelope. They are seen as buds when small, but often with the increasing size of the germ, as longer processes. These are particularly noticeable in mammals (figs. 14, 15, 16, 17, 18).

The relation of the buds and processes of the epithelial envelope to the capillary blood-vessels is very striking. The association is most marked where active proliferation is in progress (figs. 16, 26).

As the crown of the tooth nears completion the cells of the envelope become compressed on to the other remaining cells of the enamel organ to form the epithelial lining of the tooth follicle (fig. 21). The tooth and its epithelial envelope as they increase in size, approach the surface, a movement largely due to the changes in the mesoderm taking place at the unenclosed part of the envelope (the base of the tooth) with lengthening of the root.

The final function of the epithelial envelope is the formation of the epithelial structures over the crown of the tooth and assistance in fixation at its ultimate position (fig. 20).

The character of the mesoderm around the mammalian germ presents constant and special features. It is composed of very delicate fibres which stain but feebly with collagen stains, and some scattered nuclei. Its appearance is so striking that we have called it the "Stellate Mesoderm" on account of its close resemblance to the "stellate reticulum" of the enamel organ for which in fact it may be mistaken. It is so characteristic a feature in the early stages of a developing tooth in mammals, that an approaching germ can be predicted from the appearance of the stellate mesoderm in some sections of a series before the germ itself appears (fig. 26).

(*b*) *Sheath epithelium or sheath of Hertwig:* This is an extension from the coronal margin of the epithelial envelope together with a similar extension from the internal epithelium of the enamel organ. It surrounds the subcoronal part of every tooth whether ankylosed or socketed (figs. 9, 10, 11, 12). In the latter we have called it the Root Sheath Epithelium (figs. 20 and 21).

It has been described in amphibia by Hertwig (1874); in rodents, ungulates and carnivora by von Brunn (1887, 1891); and by Mummery (1924) and others, also by Tomes (1923) in some detail in human teeth. The presence of special dental epithelial cells is necessary for the formation of dentine, this has long been recognized and has recently been confirmed by the experimental work *in vitro* by Miss Glasstone (1930 and 1938).

In certain lower types of animals a sharp distinction cannot be drawn between the coronal part of the epithelial envelope and the subcoronal part or sheath epithelium.

but where enamel is present on the crown, as in mammals, the sheath epithelium can be clearly defined as that part beyond the region of enamel formation.

Two groups occur according to the nature of the attachment of the tooth. On ankylosed teeth the sheath is widely open and bell shaped (figs. 5, 9, 11), but on rooted teeth it is conical in form, being narrowed at the apex (fig. 20).

At first the extension is intact forming a continuous layer of cells, later this condition may persist when fixation of the tooth is by a bone of attachment, as in acrodonts, but in socketed teeth, which are attached to the bone by a periodontal membrane as in crocodilia and most mammals, the continuity is interrupted by the formation of the principal fibres of the membrane rendering it fenestrated (figs. 20 and 21).

The group selachia appears to be an exception. The epithelial envelope in these animals (dog-fish) surrounds the developing tooth as far as the expanded base of the tooth beyond which development occurs without the influence of the dental epithelium (fig. 4).

The sheath epithelium is universally present around the implanted part of calcified teeth.

In the teleostomi development of successional germs occurs from the sheath epithelium in all the specimens of this subclass of fishes that we have examined (figs. 1, 2, 3). Charles Tomes (1876) in his classical paper on "The Development of the Teeth of Fishes" makes the statement that "in teleostei the new enamel germs are formed directly from the oral epithelium, and are new formations arising quite independently of any portion of the tooth germs of the teeth which have preceded them". This may be true only of the first tooth of a series but all successional germs are formed by a proliferation of some part of the sheath epithelium of a preceding tooth.

The opinion expressed by Tomes has probably been responsible for the generally accepted view as to the origin of the successional teeth of these fishes, that each one arises independently of its predecessor by a separate proliferation from the oral epithelium.

Von Heinke (1873), however, has described the new enamel organs of pike as being derived from older ones. This observation does not appear to have been extended to other fish. There is a remarkable resemblance between this form of origin and that seen in the replacement of a hair in mammals.

In all lower forms where the teeth are ankylosed, the sheath epithelium completely surrounds the tooth and is in continuity with the surface epithelium so that the teeth are embedded in epithelium which extends as far as the bone of attachment (figs. 8 and 9).

The sheath epithelium as it is found on the completed mammalian tooth can only be effectively demonstrated in reconstruction models which show it as an epithelial network surrounding the root. In individual sections it is seen as the familiar epithelial "rests" (figs. 20 and 21).

(4) The Connecting Dental Epithelium

This is the name we have given to the dental epithelium which connects the germs and developing teeth of a dental unit to each other and to the surface. It is formed by proliferation of the cells of the dental lamina, with some from the epithelial envelope and the surface dental epithelium. As connecting dental epithelium it consists of threads, columns or bands of cells often forming a network in mammals (the intermediary plexus of Malassez in man) (fig. 22). In polyphodonts with persistent laminæ the connexions are established and maintained by the lamina to which the developing teeth are attached until they reach the surface epithelium (figs. 4 and 5). In holostei and teleostei the connexions are brought about by the sheath epithelium of the functional tooth where proliferation of its cells may form either an epithelial bud close to it, or a column of cells leading to the new germ. This column is of varying length in different or even in the same species (figs. 1, 2, 3).

In amphibia and some reptilia (snakes) a persistent lamina provides the connexions (figs. 5, 9, and 23). In crocodile, there is constantly found a process of epithelium connecting successional germs shown in reconstructed models and photographs (fig. 23).

In diphyodont mammals direct connexion is not so easily established. The early stages are simple but the rapid proliferation of the lamina cells and the development of the connexions between the epithelial envelope of the deciduous germ and the lamina, together with the changes in the latter render interpretation difficult. Here the connecting dental epithelium is seen as a network consisting of columns or nodes if cut across. Tortuous columns do not appear to be continuous if a single section only is examined, but the examination of a series puts the matter beyond doubt. The greatest activity is in the region of the epithelial envelope (figs. 14, 15, 16, 17 and 18).

It would seem that the attachment between the connecting dental epithelium and the surface epithelium during the earlier periods is not more than a fine strand, for there is difficulty in establishing the exact attachment. If this is so the great accuracy of the points of eruption would be established.

The recognition of the proliferations of the dental epithelium contradicts the generally accepted view that the dental lamina is lost (figs. 24 and 25). This applies in particular to man where only functionless remnants are said to persist. It certainly does not disappear in the lower forms of animals, and the connexions of its proliferations with the epithelial envelope and the surface dental epithelium constitute the continuity in the higher forms, including man (figs. 24 and 25).

(5) Surface Dental Epithelium

This is that part of the surface epithelium in a dental zone which undergoes proliferation of its deeper cells. If forms the most superficial part of the connecting dental epithelium.

It may persist from the initial formation of the dental epithelium (fig. 6), but in all animals it occurs as an active proliferation prior to the eruption of a tooth. It can be seen over the erupting teeth of such divergent animals as fishes, amphibia, reptiles and mammals (fig. 21).

The final position of a tooth is established in mammalia by the junction of the epithelial envelope with the surface epithelium (fig. 20).

In the lower forms the loss of surface cells is most marked calling for rapid replacement, and there can be no doubt that this rapidity of waste and repair is an important feature in the movement of the successional teeth to the surface. This aspect of the subject, however, belongs, strictly speaking, to eruption which we have not dealt with except indirectly, in this paper.

Summary

(1) Tooth development in all tooth-bearing animals is essentially the same.

(2) It depends primarily upon the differentiation of certain cells of the surface epithelium of the mouth with potentialities for tooth formation.

(3) The various epithelial structures resulting from the proliferation of these specialized cells constitutes the dental epithelium.

(4) It is convenient to describe four different sites of origin of tooth germs following the initial proliferation:

(*a*) Surface Epithelium. (*b*) Sheath Epithelium. (*c*) Persistent Dental Lamina. (*d*) Non-persistent Dental Lamina.

(5) The initial proliferation determines the position of the developing germ and the point of eruption. The position of successional germs, and their eruption points are also pre-determined at the same time. Thus the original inflection that fixes the position of the minute teeth in the jaws of the newly-hatched crocodile, predetermines the position of the immensely larger teeth of the adult animal.

(6) Emphasis has been laid upon the importance of the dental epithelium in positioning the tooth, directing its path of eruption, establishing union at the surface and fixing it in its functional position.

(7) We have classified the dental epithelium under headings which possess definite morphological and functional features. Thus it forms a "dental epithelial framework" distributed throughout the tooth-bearing areas of the jaws, which in its various manifestations as "surface dental epithelium" the "epithelial envelope" and "connecting dental epithelium" joins up the individual elements of a "dental unit" and finally establishes their relationship both at the surface and with each other. The tooth-bearing region with its accompanying mesodermal structures constitutes the "dental zone."

(8) A dental unit contains all the individual teeth which are produced from one germ centre, and so is applicable to monophyodont, diphyodont and polyphyodont dentitions. The epithelial envelope controls the position of the tooth throughout the whole process of development. Proliferations of its cells on the coronal portion give rise to buds and processes which are associated with its progressive development and change of position. These proliferations together with those from the dental lamina and surface dental epithelium form the connecting dental epithelium.

(9) Origin of successional tooth germs from proliferation of the sheath epithelium is described in some teleostomi in contradiction of Charles Tomes, who states that each successional germ is derived by a new proliferation of the surface epithelium.

(10) Attention is drawn to the very striking resemblance of the sheath epithelium of a hair follicle to that of a tooth and the manner in which each is connected with the surface epithelium. There is also a developmental similarity.

(11) Contrary to the statement of Bolk that an "enamel septum" is not found in the enamel organs of reptilia, the presence of both an "enamel septum" and an "enamel navel" are shown in *Caiman crocodilus*.

(12) In teleostomi the sheath epithelium has an added significance as it is by proliferation of its cells and not those of the surface epithelium that the successional germs are derived. Also attention is drawn to the role of the dental epithelium in the restoration of the surface epithelium following the loss of teeth notably from the sheath epithelium, as in the eel (*Anguilla vulgaris*).

(13) The connecting dental epithelium of the mammalian dentition is complex, its proliferations play a prominent part in maintaining connexion between the developing tooth and the surface. The extent of the proliferations over both deciduous and permanent germs does not appear to be realized; but after a study of many series of different animals we are convinced that the marked proliferations are of great importance in directing the path of eruption and guiding the tooth to its correct position.

(14) The activity of the cells of the surface dental epithelium as shown by the marked proliferation over and around the erupting tooth is obviously of great importance in establishing the tooth in its functional position. We have found it in all animals but it is especially pronounced in some teleostei such as *Esox lucius, Anguilla vulgaris,* salmon, &c.

This short exposition and summary is an attempt to establish the supreme importance of the dental epithelium in initiating and controlling tooth development and eruption and the final positioning of the teeth.

LIST OF ANIMALS EXAMINED

Serial sections were cut of all that were sufficiently well fixed.

Selachii

Dog-fish—*Scyllium canicula. Scyllium catulus.*
Shark—(unknown).
Electric Ray—*Narcobutus torpedo.*

Teleostomi

Long-nosed garpike—*Lepidosteus osseus.*
Pike—*Esox lucius.*
Eel—*Anguilla vulgaris. Conger vulgaris.*
Whiting—*Gadus merlangus.*
Cod—*Gadus morrhua.*
Hake—*Merluccius vulgaris.*
Trout—*Salmo fario.*
Sea-trout—*Salmo trutta.*
Salmon—*Salmo salar.*
Chub—*Leuciscus cephalus.*
Perch—*Perca fluviatilis.*
Mackerel—*Scomber scombrus.*
Blenni—*Blennius gattorugine.*
Catfish—Species unknown.
Swallow-tailed wrasse—*Julis pavo.*
Goldfinny wrasse—*Ctenolabrus rupestris.*
Larger Bull-head—*Cottus bubalis.*
West Indian fish—Cichlid? (This fish was caught in the presence of one of us off Trinidad where the fresh water from the Orinoco extends far out to sea and is muddy. On this account in spite of being caught in the sea it was thought to be a Cichlid but was not classified.)

Amphibia

Newt—*Triton tœniatus.*
Axolotl—*Amblystoma tigrinum.*
Frog—*Rana temporaria, Rana tigrina, Rana catesbiana.*

Reptilia

Spectacled caiman—*Caiman crocodilus.*
Broad-nosed caiman—*Caiman latrinostris.*
Nile crocodile—*Crocodilus niloticus.*
Blind worm—*Anguis fragilis.*
Chameleon—*Chamœleon vulgaris.*
Wall lizard—*Lacerta muralis.*
Reticulate python—*Python reticulatus.*
Adder—*Pelias berus.*

Mammalia

Red kangaroo—*Macropus rufus.*
Bennett's tree-kangaroo—*Dendrolagus bennetti.*
Wallaby—*Macropus ruficollis bennetti.*
Pig—*Sus scrofa.*
Indian mouse deer—*Tragulus meminna.*
Rat—*Mus decumanus.*
Mouse—*Mus musculus.*
Squirrel—*Sciurus vulgaris.*
Rabbit—*Lepus cuniculus.*
Lion—*Felis leo.*
Tiger—*Felis tigris.*
Cat—*Felis domestica.*
Syrian bear—*Ursus arctos syriacus.*
Dingo—*Canis familiaris dingo.*
Hedgehog—*Erinaceus europœus.*
Lemur—*Galago moholi.*
Homo—*Homo sapiens.*

BIBLIOGRAPHY

BOLK, L. (1912) *Anat. Anz.*, **41**, Suppl. 58-68.
—— (1921) *J. Anat., Lond.*, **55**, 138, 219.
—— (1922) *J. Anat., Lond.*, **56**, 107.
GLASSTONE, S. (1936) *J. Anat., Lond.*, **70**, 260.
—— (1938) *Proc. Roy. Soc.*, **126**, 315.
HARRISON, H. S. (1901) *Quart. J. micr. Sci.*, **44**, 161.
HERTWIG, O. (1874) *Arch. mikr. Anat.*, **11**, Suppl. 1-208.
JAMES, W. WARWICK (1909) *Proc. R. Soc. Med.*, **2**, Sect. Odont., 163.
MUMMERY, J. HOWARD (1924) The Microscopic and General Anatomy of the Teeth, London.
RÖSE, CARL (1891) *Arch. mikr. Anat.*, **38**, 447.
—— (1892) Über die Zahnentwicklung des Reptilien, Berlin.
TOMES, C. S. (1876) *Philos. Trans.*, **165**, 257.
—— (1923) A Manual of Dental Anatomy, Human and Comparative. 8th Ed. by H. W. Marett Tims and C. B. Henry, London.
von BRUNN, A. (1887) *Arch. mikr. Anat.*, **29**, 367.
—— (1891) *Arch. mikr. Anat.*, **38**, 142. *Dtsch. Mschr. Zahnheilk.*, **10**, 127.
von HEINKE, F. (1873) *Z. wiss. Zool.*, **22**, 495.
WELLINGS, A. W. (1938) Practical Microscopy of the Teeth and Associated Parts, London.
WOERDEMAN, MARTIN W. (1919) *Arch. mikr. Anat.*, **92**, 104.

PROC. ROY. SOC. MED.
Vol. XXXVII, No. 1.
Section of Odontology.

PLATE I.

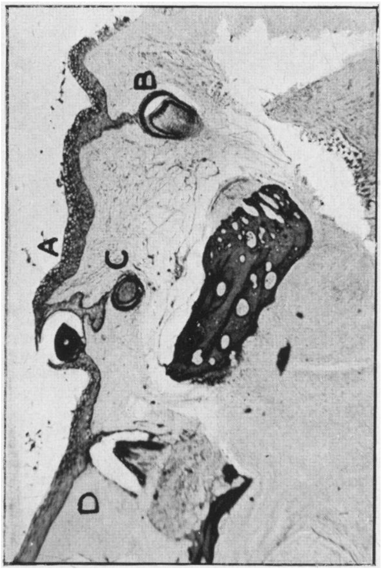


FIG. 1.

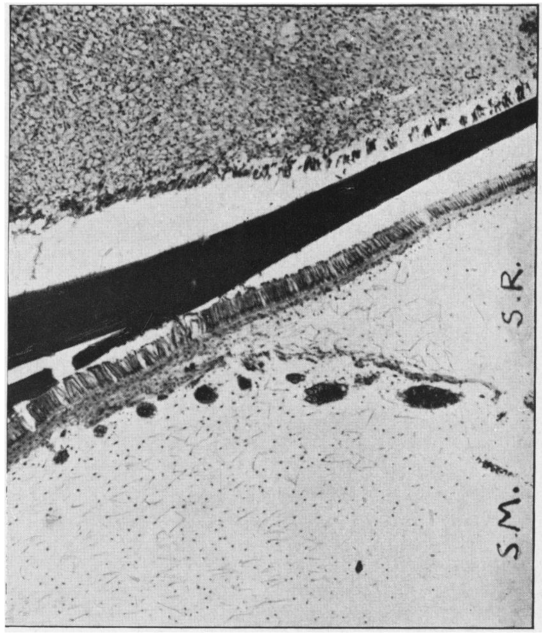


FIG. 26.

FIG. 1.—Pike (*Esox lucius*). × 30. A, surface epithelium connecting dental units. It forms part of the epithelial framework of a dental zone; B, origin from the surface epithelium or sheath epithelium; C, origin from the sheath epithelium; D, direct origin from the surface epithelium.

FIG. 26.—Lion (fœtal). × 70. Resemblance of the stellate mesoderm (S.M.) to the stellate reticulum (S.R.) Vessels intermitting with buds of the epithelial envelope in the stellate mesoderm.

FIG. 2.

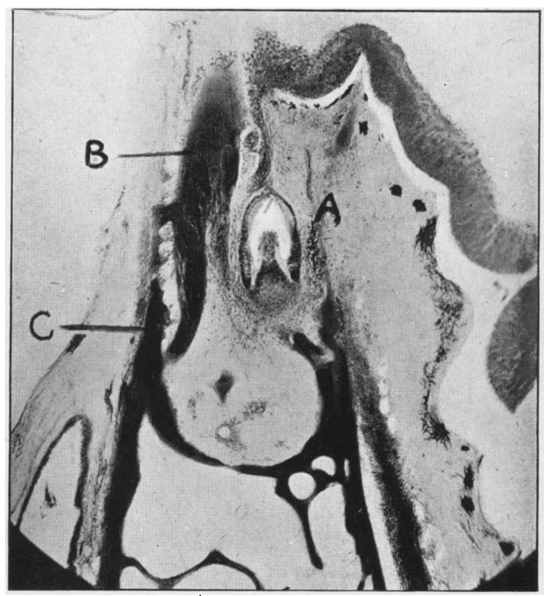


FIG. 3.

FIG. 2.—Cat fish. × 90. A, functional tooth; B, proliferation of the sheath epithelium from which C, a new dental germ, is arising.

FIG. 3.—Mackerel (*Scomber scombrus*). × 55. A, dental germ arising from the sheath epithelium connected with B, the remnant of a functional tooth which is attached to C, the bone.

W. WARWICK JAMES and A. W. WELLINGS:
The Dental Epithelium and its Significance in Tooth Development.

PLATE II.

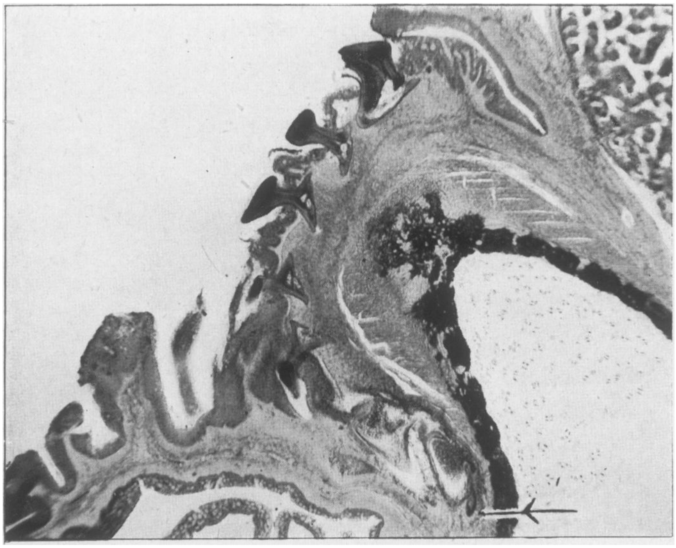


FIG. 4.—Dogfish. × 17. Origin of germs from a persistent dental lamina which is marked at its terminal margin by an arrow. The section is cut almost on one plane of a dental unit.

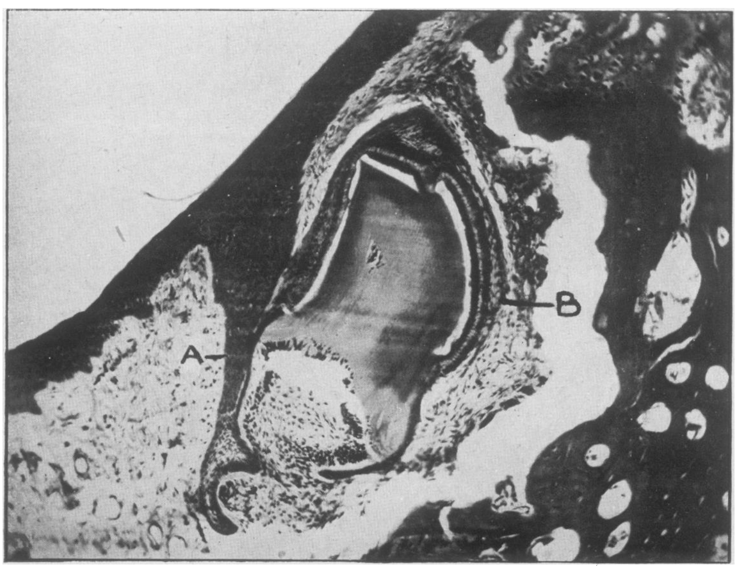


FIG. 5.—Frog (*Rana catesbiana*). × 250. A, persistent dental lamina with a developing tooth attached and a new dental germ forming at its terminal margin. The epithelial envelope, B, is seen in section.

W. WARWICK JAMES and A. W. WELLINGS: The Dental Epithelium and its Significance in Tooth Development.

PROC. ROY. SOC. MED.
Vol. XXXVII, No. 1.
Section of Odontology.

PLATE III.

FIG. 6.—Human fœtus (length not known) cut vertically across two central incisors. × 22. Origin of a dental germ from a non-persistent dental lamina. S.D.E., surface dental epithelium; D.L., dental lamina which is proliferating. passing from the thickened surface epithelium; C.D.E., connecting dental epithelium as a short column from the D.L. to the epithelial envelope (E.E.).

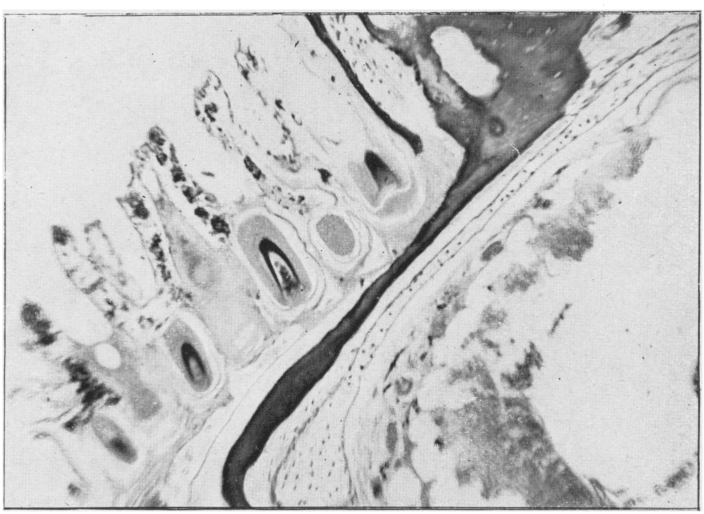


FIG. 7.—Lizard (*Lacerta muralis*). × 55. Sockets of discarded teeth and successional germs showing part of the epithelial framework.

W. WARWICK JAMES and A. W. WELLINGS: The Dental Epithelium and its Significance in Tooth Development.

PLATE IV.

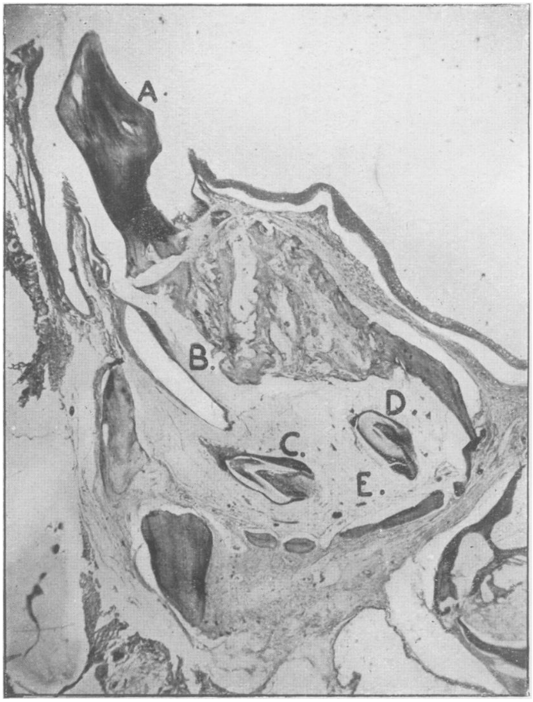


FIG. 8.—Wrasse (*Ctenolabrus rupestris*). × 16. A, functional tooth ; B, epithelial envelope, from which the tooth is lost, attached to the sheath epithelium by connecting dental epithelium ; C and D, younger germs ; E, in area of tooth development.

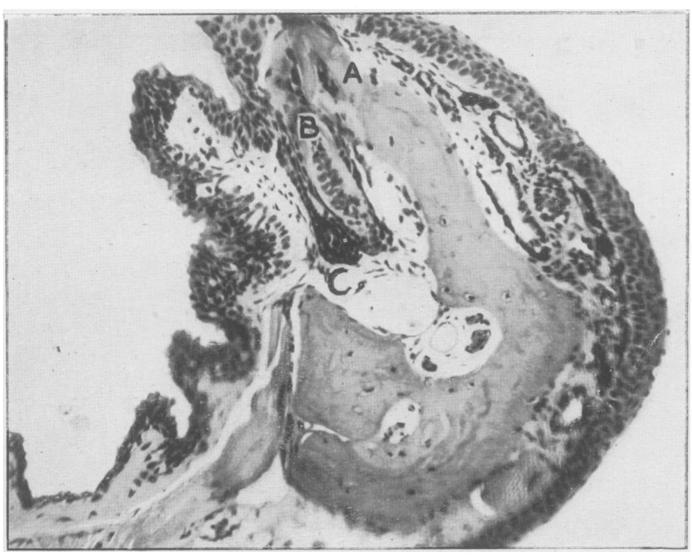
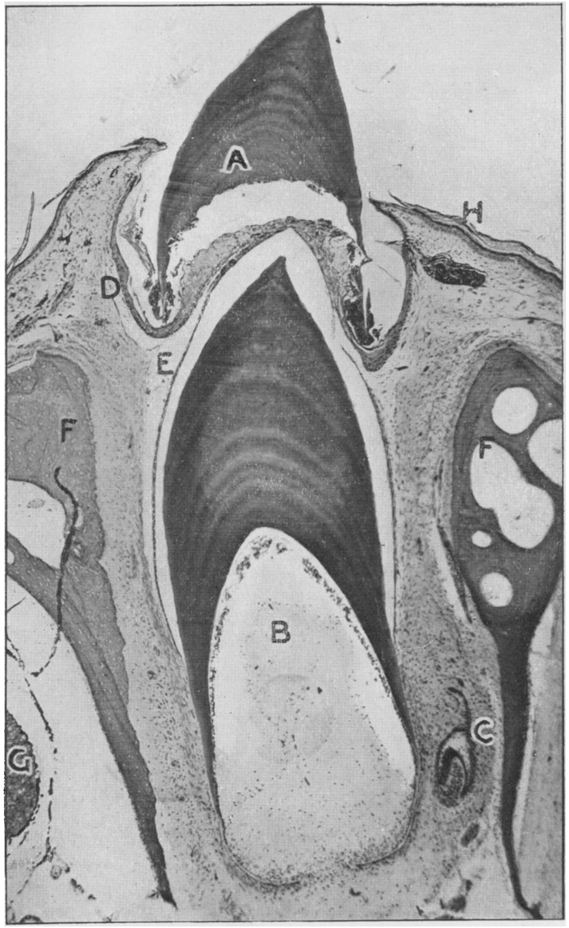


FIG. 9.—Newt. × 90. Showing a dental unit. A, base of functional tooth ; B, developing successional tooth attached to a persistent dental lamina, with C, the youngest member at the terminal margin.

W. WARWICK JAMES and A. W. WELLINGS:
The Dental Epithelium and its Significance in Tooth Development.

PROC. ROY. SOC. MED.
Vol. XXXVII, No. 1.
Section of Odontology.

PLATE V.



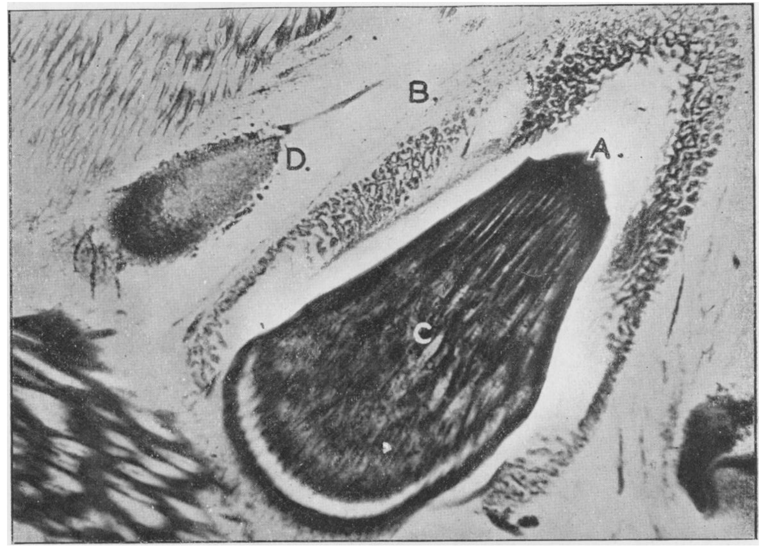


FIG. 11.—West Indian fish (? Cichlid). × 35. A, advanced stage of a developing tooth partly encapsuled by B, the epithelial envelope; C, formed dentine; D, young germs with connecting dental epithelium projecting from its epithelial envelope.

FIG. 10.—Caiman. × 50. Dental unit. A, functional tooth being absorbed; B, successional tooth; C, new germ with part of connecting dental epithelium at summit; D, Subgingival epithelium; E, epithelial envelope of successional tooth; F, alveolar bone; G, nerve; H, surface epithelium. The epithelial envelope of the successional tooth is uniting with the subgingival epithelium of its predecessor.

W. WARWICK JAMES and A. W. WELLINGS:
The Dental Epithelium and its Significance in Tooth Development.

PROC. ROY. SOC. MED.
Vol. XXXVII, No. 1.
Section of Odontology.

PLATE VI.

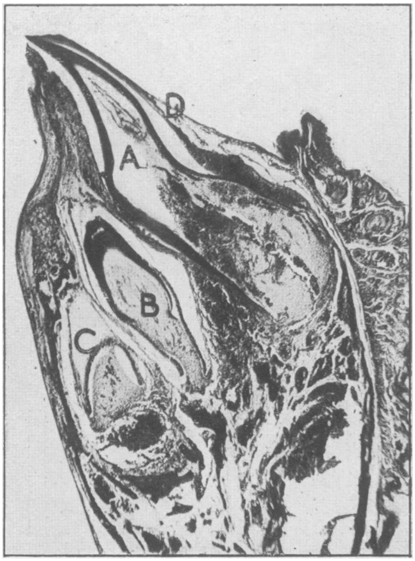


FIG. 12.

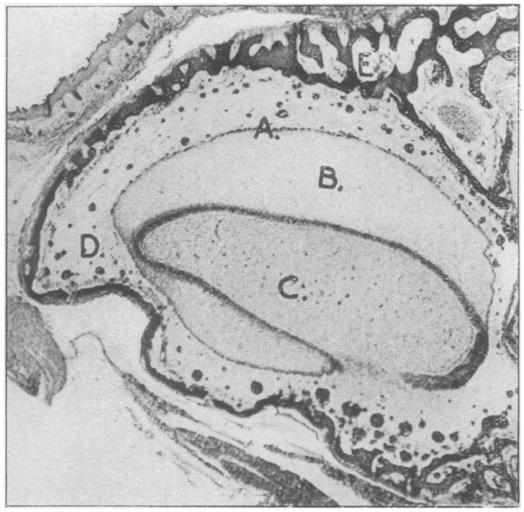


FIG. 13.

FIG. 12.—Lemur (*Galago moholi*). × 20. Showing epithelial envelopes (A, first incisor ; B, second incisor ; C, third incisor or canine) of the procumbent mandibular teeth in different stages of development ; D, epithelial envelope of first incisor.

FIG. 13.—Wallaby (*Macropus ruficollis bennetti*). × 30. Transverse section of the germ of an incisor showing the epithelial envelope, A, almost enclosing it ; B, stellate reticulum ; C, pulp ; D, mesodermal tissue with many capillaries, outside the envelope ; E, alveolar bone.

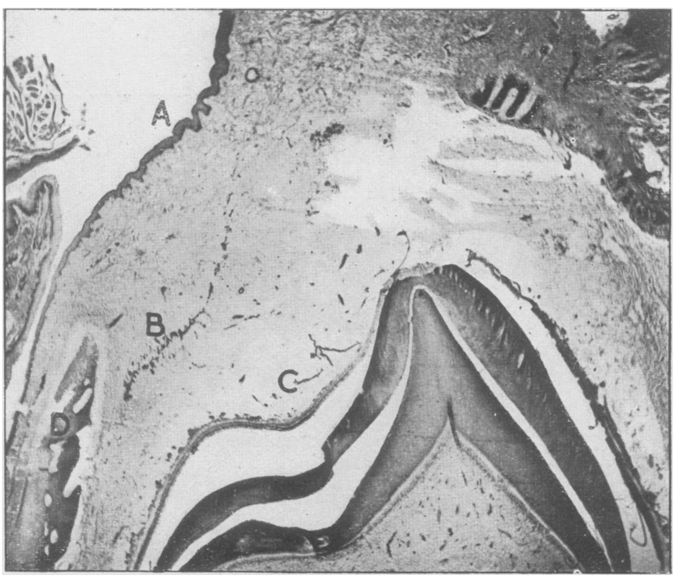
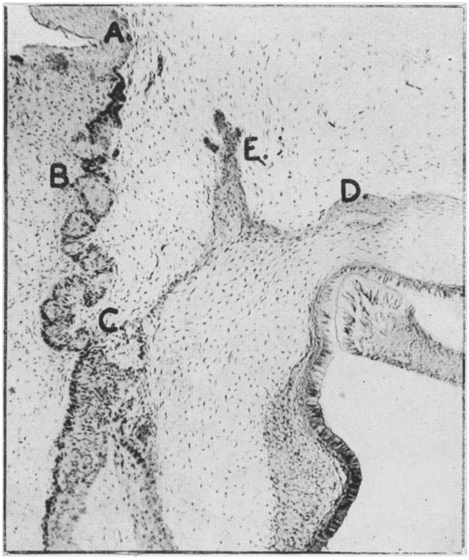


FIG. 14.—Human fœtus. Vertical bucco-lingual section of mandible. × 14. A, surface epithelium ; B, proliferating dental lamina ; C, buds and processes from epithelial envelope of developing tooth with formed enamel and dentine ; D, bone of crypt.

W. WARWICK JAMES and A. W. WELLINGS :
The Dental Epithelium and its Significance in Tooth Development.

PROC. ROY. SOC. MED.
Vol. XXXVII, No. 1.
Section of Odontology.

PLATE VII.



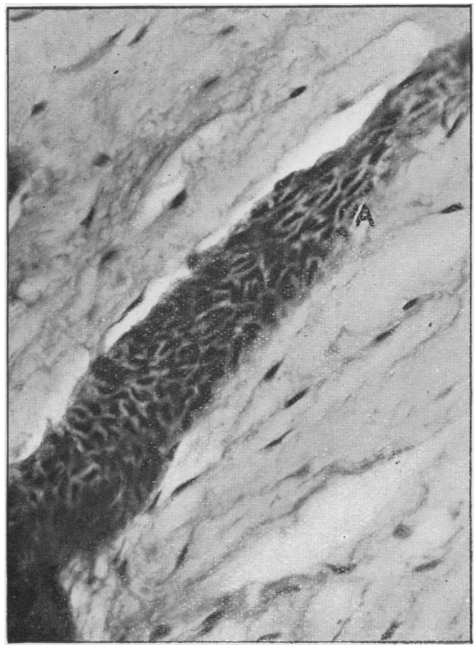


FIG. 15.

FIG. 18.

FIG. 15.—Human fœtus. × 55. Incisor early germ. A, surface dental epithelium ; B, dental lamina proliferating and forming connecting dental epithelium which is attached at C to the epithelial envelope ; D, E, proliferation from the epithelial envelope forming a projecting process.

FIG. 18.—Human fœtus. × 335. A, process from the epithelial envelope.

FIG. 19.—Caiman (*Caiman crocodilus*). × 80. A young animal. The epithelial envelope encapsulating a developing tooth, outside the stellate reticulum. The summit of the enamel organ shows an "enamel navel" from which an "enamel septum" passes to the inner layer of cells as is seen in mammals.

W. WARWICK JAMES and A. W. WELLINGS:
The Dental Epithelium and its Significance in Tooth Development.

PLATE VIII.

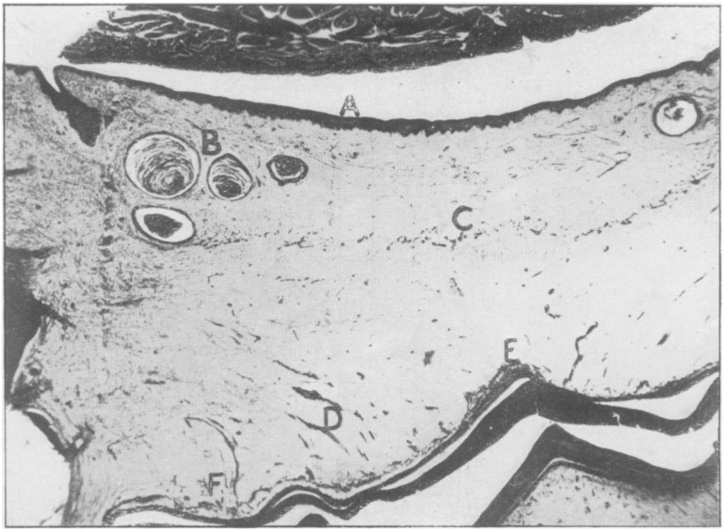


FIG. 16.—Human fœtus. × 14. A, surface epithelium; B, epithelial coils and surface dental epithelium with characteristic depression; C, proliferating dental lamina; D, buds and processes from E, the epithelial envelope; F, capillaries associated with buds and processes.

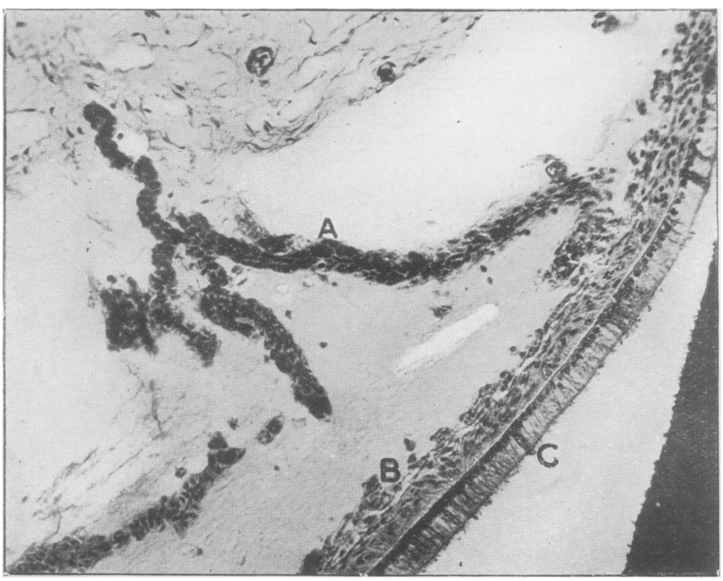
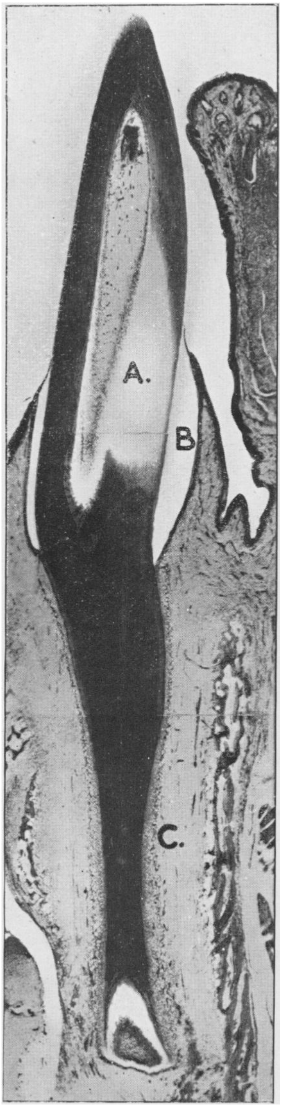


FIG. 17.—Human fœtus. × 125. Higher magnification of fig. 16, showing A, process from B, epithelial envelope; C, ameloblasts.

W. WARWICK JAMES and A. W. WELLINGS:
The Dental Epithelium and its Significance in Tooth Development.

PROC. ROY. SOC. MED.
Vol. XXXVII, No. 1.
Section of Odontology.

PLATE IX.



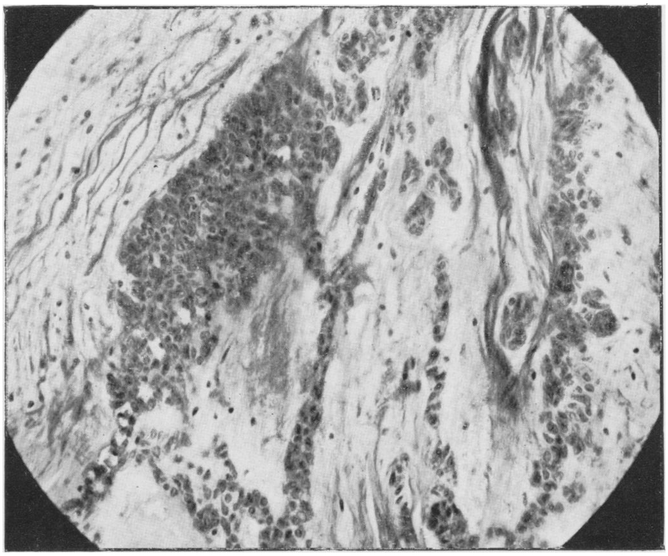


FIG. 22.

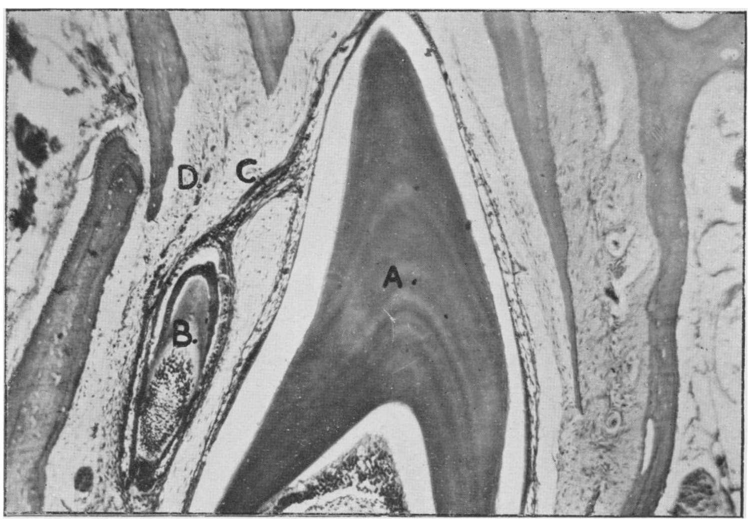


FIG. 20.

FIG. 23.

FIG. 20.—Pig. Newly born. × 11·5. Continuity between the root sheath epithelium C, which is fenestrated, and B, the subgingival epithelium with the epithelial attachment. A, functional tooth and its epithelial envelope which has almost attained its final relationship.

FIG. 22.—Human. × 225. Connecting dental epithelium which has been formed by proliferation of cells of the dental lamina.

FIG. 23.—Caiman. × 80. The connecting dental epithelium, C, passes between the epithelial envelope of the developing tooth, A, and the germ, B, with which the dental lamina, D, is just seen to be connected.

W. WARWICK JAMES and A. W. WELLINGS: The Dental Epithelium and its Significance in Tooth Development.

PLATE X.

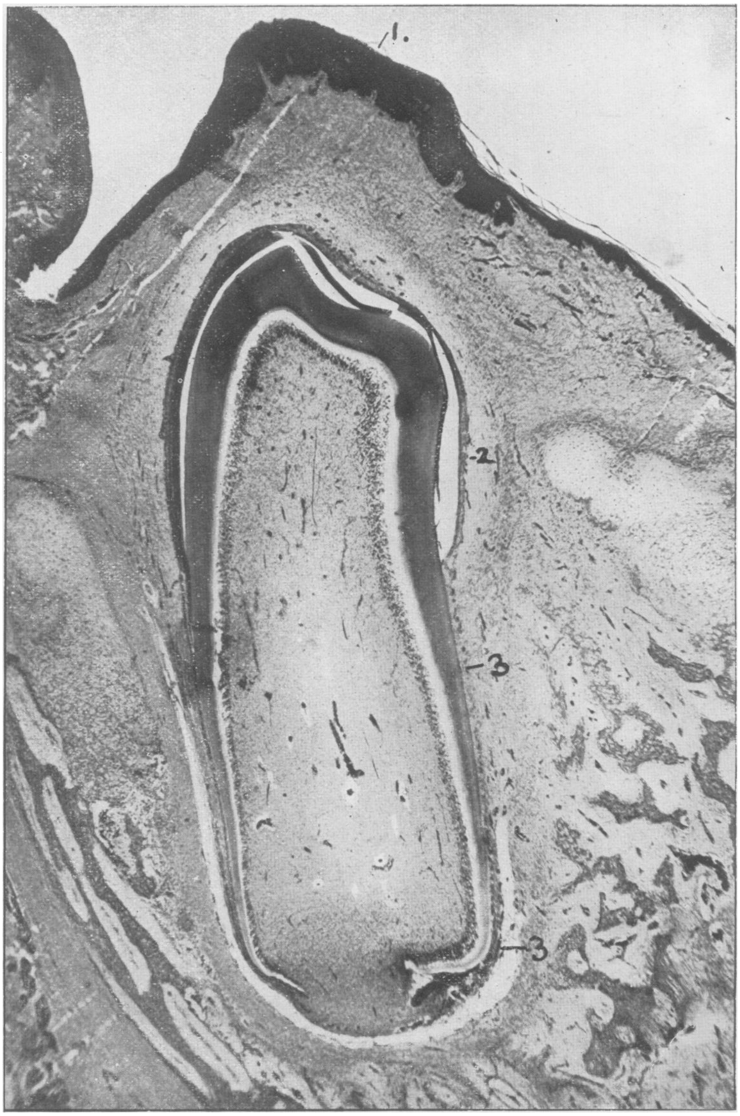


FIG. 21.—Tiger (at birth). × 30. Section of a developing tooth prior to eruption showing 1, proliferation of the surface dental epithelium above it; 2, coronal part of the epithelial envelope which is continuous with the subcoronal part 3, the root sheath epithelium which shows fenestration. The apical mesoderm is undergoing active proliferation.

PLATE XI.

FIG. 24

FIGS. 24 and 25.—Human. × 30. From the same series a few sections apart. The network of connecting dental epithelium in fig. 24 and the absence of any cells in the tissues above the tooth in fig. 25 are striking : a possible explanation of the statement that these cells disappear.

PLATE XII.

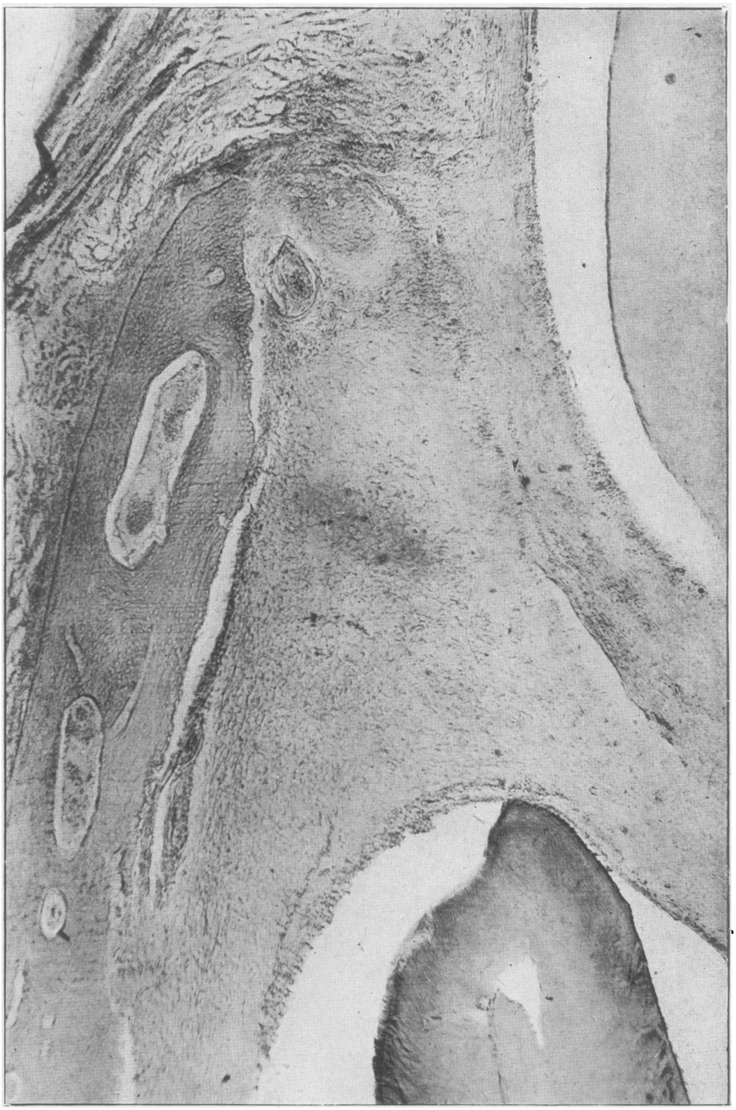


FIG. 25

FIGS. 24 and 25.—Human. × 30. From the same series a few sections apart. The network of connecting dental epithelium in fig. 24 and the absence of any cells in the tissues above the tooth in fig. 25 are striking: a possible explanation of the statement that these cells disappear.